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A MOISTURE ISOLATION UNIT FOR SWINE

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INTRODUCTION

To measure the moisture lost by an animal, all that is required is a moisture-proof container (room or tent), air circulating through the container over the animal, and sensing elements to measure the moisture contents of incoming and outgoing air. The difference in these moisture contents of the air is a measure of the total moisture lost by the animal. Bond, Kelly, and Heitman (3)[5] described such a facility for swine in which the incoming air temperature and moisture content were controlled. Determination of moisture losses of an animal can be further refined by eliminating evaporation of moisture from the urine and/or feces. Such a system is described by Yeck and Kibler (7) for use with cattle.

Brody and Kibler (4) refer to water vaporization from the respiratory-oral system as amounting, in nonsweating species, to nearly all of the total water vaporized. There is no question that in (nonsweating) panting animals the pulmonary ventilation serves to cool the animal, and that this ventilation rate varies with the environmental temperature. Since the pig is considered a nonsweating animal, measurement of the total moisture loss could be refined further by investigating the magnitude of moisture evaporated from each of the two sources--oral passages and skin.

Several restraining frames or metabolism units have been reported for use with swine (1, 2, 5). These are intended for nutritional studies of intake (feed and water) and body discharge (urine and feces) over relatively long periods. None of these provide a means of separating pulmonary ventilation from the other physiological functions.

The procedure adopted for separating the surface and respiratory moisture was: (1) Finding the total moisture lost by the pig, measured by the increase in moisture content of air passing over the pig restrained in a moisture-proof tent; (2) finding the moisture loss from the skin only by placing a mask over the pig's snout so that the air it breathed was drawn from and exhausted outside the tent.

This paper describes the design and operation of a system for isolating and measuring the moisture evaporated from the oral passages and skin of swine. The system was designed for use with pigs weighing 50 to 200 lb. (23 to 90 kg.).

The system and method include the following components: (1) Snout mask and a suitable harness to hold the mask in place; (2) restraining frame to restrict the pig to a relatively small

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space; (3) tent, air- and moisture-tight, to envelop the restraining frame and permit the separation of expired air from air circulating over the body; (4) training of the pig to be subjected to the above conditions for periods up to 1 hour or more; and (5) instrumentation to measure both the total moisture evaporated from the pig and that evaporated from the skin.

MASK

The function of the mask is to cover the snout of the pig in front of the eyes and seal off the respired air from the rest of the body. Provision was made to supply fresh air to the mask from outside of the tent and also remove the expired air from the mask to the outside of the tent.

In the design of the mask several materials were considered for sealing around the snout. Small innertubes were found to be best since various sizes could be properly inflated to accommodate the wide range of head sizes of pigs from 50 to 200 lb., and of different breeds. Two sizes of industrial pneumatic innertubes were used, 2.50 X 4 for smaller pigs and 3.00 X 5 for larger pigs. The general shape and size of the mask were determined by the size of pig snout and the innertube. The approximate snout dimensions of 50- and 200-lb. Duroc pigs are as follows:

	50-lb. pig	200-lb. pig
Nose to eyes ..... in.....	5	8
Nose to back of mouth ..... in.....	3	5
Diameter at eyes ..... in.....	4	8

The valve stem of the innertube was moved to the outer surface, and a band was placed around the tube to restrict the outward expansion when inflated. In this way, the inside diameter of the innertube decreased on an increase in air pressure. The band was made a part of the mask (fig. 1), and the innertube then made a good air seal around the snout of the animal just

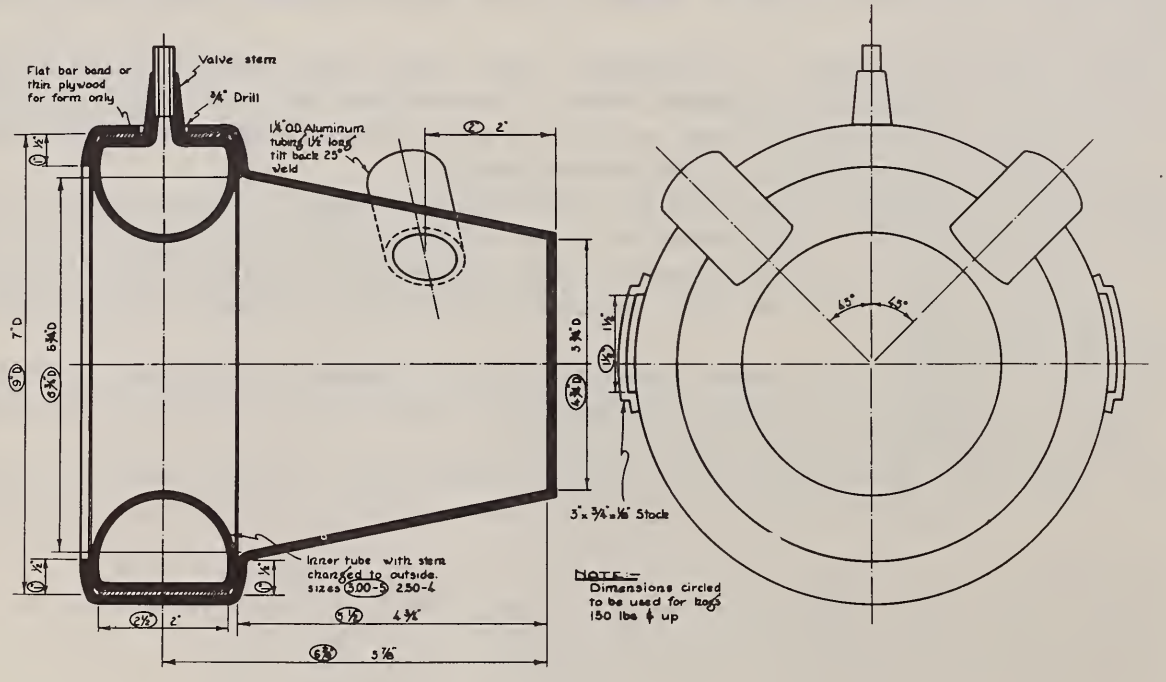

Figure 1.--Swine mask design.

in front of its eyes. With the innertube, the mask was accordingly adjustable for a range of head sizes corresponding to various body weights.

The first mask, assembled of molded Fiberglas,[6] was satisfactory. When a smaller mask was made, however, it was found that either 14- or 16-gage aluminum sheet, formed and welded, was as satisfactory and was easier to assemble.

The mask was held in place by two 1 1/4-inch woven nylon straps attached to a 1 3/4-inch woven nylon belt fastened around the rib section of the pig's body just behind its front legs. This belt was usually fastened tightly on the pig before it entered the restraining frame.

A three-way breathing valve was attached to the top of the mask, over the nose end, as shown in figure 2. This valve was then connected to inlet and exit air ports in the tent wall by flexible rubber tubing. It was later discarded because its resistance reduced the air flow sufficiently to excite the pig's breathing in the mask. Instead, the flexible tubes were connected directly to the mask at two points (inlet and outlet) over the nose end of the mask, as shown in figure 3. This arragement proved more satisfactory for breathing and for removal of the expired air from the mask.

In measuring the animals' total moisture loss, it was not necessary to have the mask in place, but it was more convenient to do so. Having the mask in place reduces the disturbing effect of handling the animal; also, any slobber from the mouth is caught in the mask and not spread in the tent. The mask, however, is not connected to the outside air ports; the inhaled air both comes from the tent and is exhausted to it. In this case it was found desirable to add a small blower within the tent to circulate tent air through the mask to help remove the expired air (near saturation) from the mask and ease the breathing of the pig. This small blower was used only when measuring total moisture (expired plus skin).

Figure 2.--Snout mask showing three-way breathing valve and woven nylon belt to secure mask on pig.

[6] Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty by the U.S. Department of Agriculture, and does not signify that the product is approved to the exclusion of other comparable products.

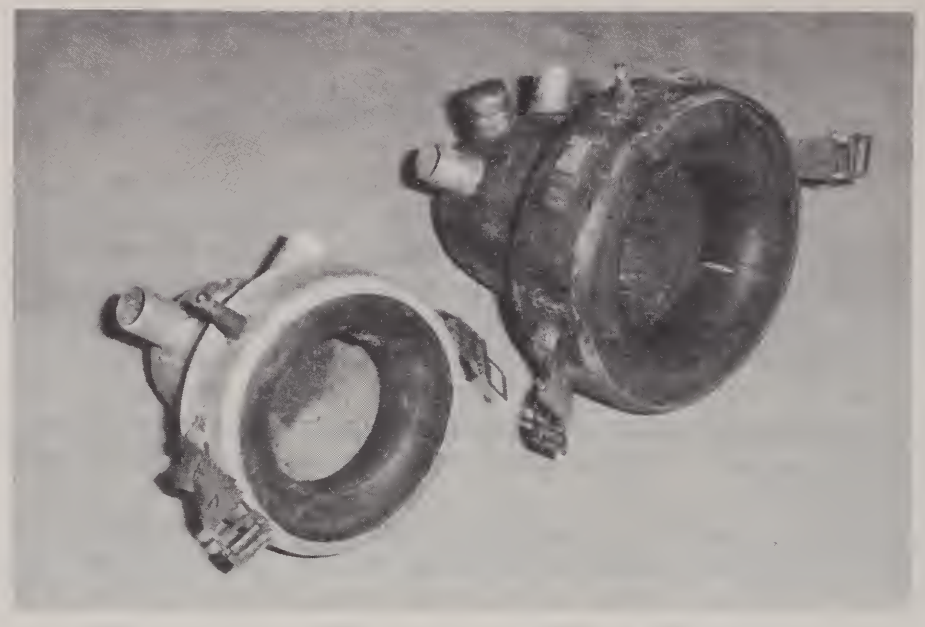

Figure 3.--Snout mask showing inlet and outlet attachments.

RESTRAINING FRAME

The restraining frame served to restrict the movement of the pig long enough to allow for the measurements--usually 1 to 2 hours. Two types of restraining frames were devised. The first type was in the form of an adjustable clamp to hold the pig in a rigid position (fig. 4). The curved arms clamped the pig from both sides behind the front legs and in front of the hind legs. The frame shown in figure 4 was adjustable for length, width, and height of pigs of different body dimensions. Since pigs placed in this frame became excessively excited, however, this type of frame was discarded as unsatisfactory.

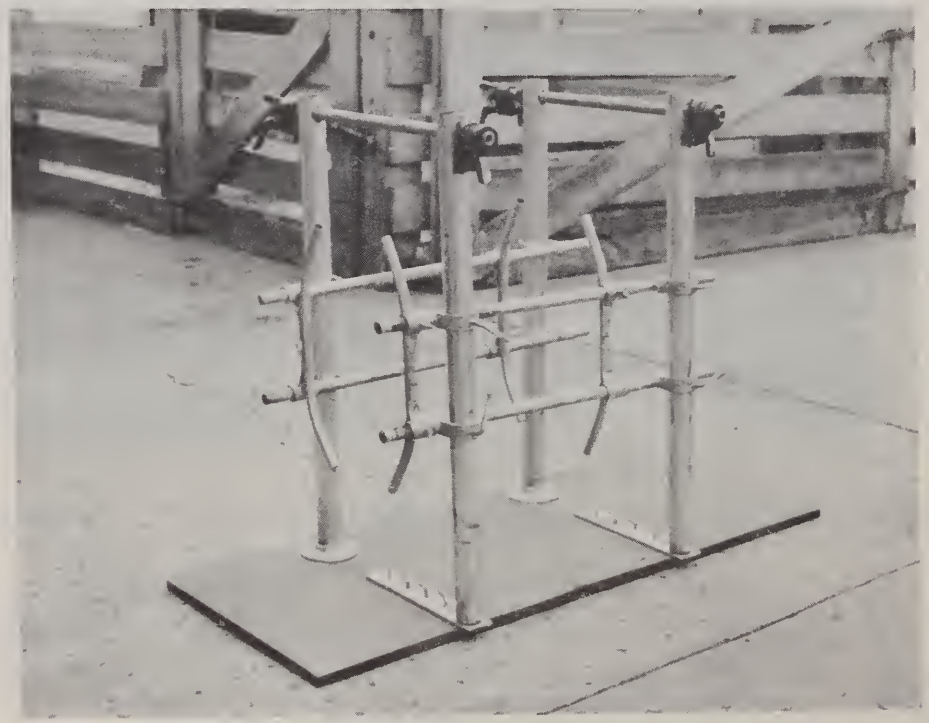

Figure 4.--Swine restraining frame, rigid clamp type, adjustable for length, width and height of animal.

The frame that was found to be best is similar to one reported by Beames (1). The present frame, shown in figure 5, has a flattened expanded-metal floor (3/4-inch, 9-11 gage) and flattened expanded-metal sides (1 1/2-inch, 9-11 gage). One side is adjustable to handle pigs weighing 50 to 200 lb. Lengths of 1/2-inch pipe (18-inches long) can be placed through the expanded metal, from side to side, to prevent the pig from backing out of the frame. This also allows an adjustment for various lengths of pigs. After standing for a few minutes in the frame, the pig will assume a prone position. To keep the pig in this position, two or three lengths of pipe are then placed through the expanded metal from side to side about 2 or 3 inches above the pig.

Figure 5.--Swine restraining frame, nonrigid type with adjustable side panel.

TENT

The purpose of the tent is to provide a moisture- and air-tight enclosure around the restraining frame. The tent, except for the floor, is 1/4-inch Plexiglas so the animal and the operator will be visible to each other. The Plexiglas tent is mounted on a angle-iron frame. The floor of the tent is galvanized sheet metal. The pig enters through a hinged door at one end; access to the pig for mask and tube adjustments is through a hinged door on top of the tent, as shown in figure 6.

Air is blown into the tent through a plenum on the head end of the tent and is exhausted through a 6-inch-diameter tube in the pig access door at the other end. The air properties (dry bulb and moisture content) are determined in the entrance plenum and in the exhaust tube.

Air for breathing is drawn through the mask in flexible rubber hose connected to flanges in each side of the tent wall, approximately opposite to the mask when on the pig. Air is drawn through the mask with a vacuum cleaner to reduce the possibility of escape of exhaled air into the tent from the mask.

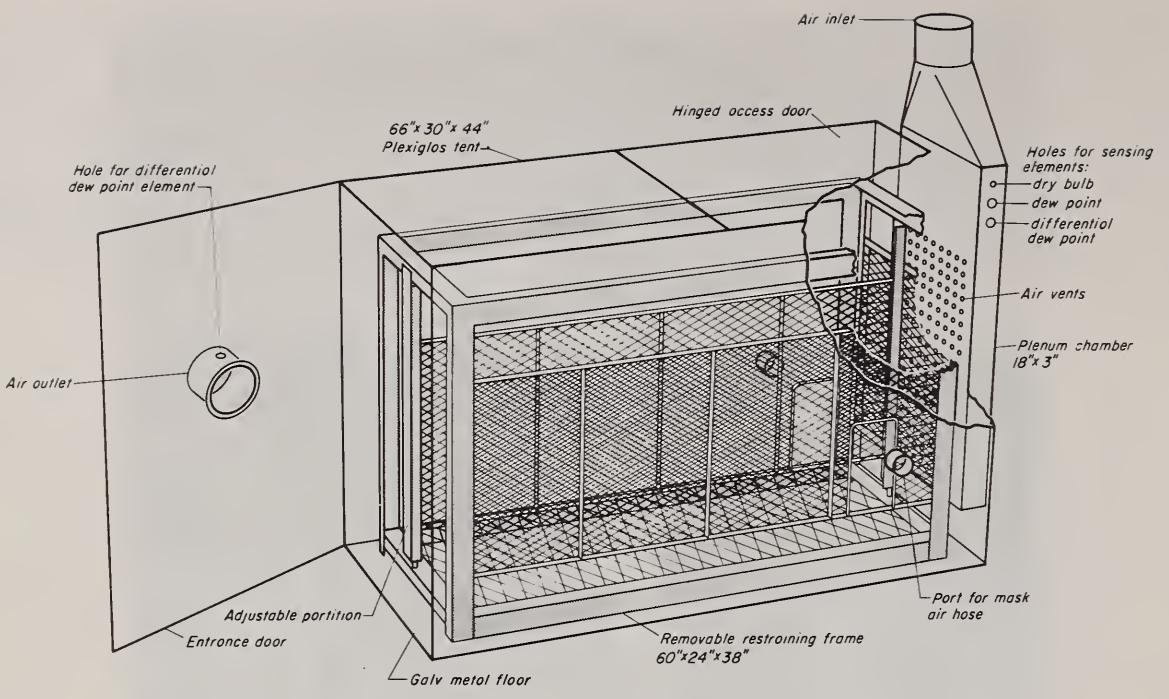

Figure 6.--Tent and restraining frame.

TRAINING OF PIGS

The pigs are first trained outside the tent, in a restraining frame similar to that used in the tent. For the first 3 or 4 days (or as long as necessary) the pig is walked into the restraining frame and remains there for about an hour at a time. To prevent the pig from backing out of the frame, two lengths of 1/2-inch pipe are placed through the expanded metal from side to side a few inches to the rear of the pig. When the pig becomes accustomed to entering the frame, it will assume a prone position after standing for a few minutes. Then, two or three lengths of 1/2-inch pipe are placed through the expanded metal from side to side about 2 inches above the pig to restrict any upward movement. This is the same procedure used when the restraining frame is in the tent.

After this preliminary training, the pig is trained to enter the restraining frame with the nylon belt buckled around the rib section, just behind the front legs. The next step of training in the frame is to put the mask on the pig's snout and attach the belt straps to hold the mask in place. After a few days the pig will cooperate in entering the frame and will allow the mask to be fitted on the snout.

An important part of the animal training is to induce urination and defecation before entering the restraining frame for a test. This can be accomplished by having the pig move around for a few minutes between the holding pen and the frame. In fact, the operator should observe the activity of the pig and make sure that it has both urinated and defecated outside the tent. If the pig should defecate after entering the frame, an attendant should be prepared to remove the feces before the tent is closed, as shown in figure 7. This precaution is necessary when the pig is assuming the prone position and the mask is being secured to the snout. If the pig does urinate or defecate in the tent during a test (this sometimes happens), then the pig has to be removed and the tent cleaned and dried before another test is made.

Figure 8 shows a pig in position in the restraining frame ready for a moisture-isolation (body only) test run. The mask is in place, with the flexible tubes connected to the tent wall to provide air for breathing and so expired air will not get into the tent.

Figure 7.--Attendant ready to remove feces before closing tent.

Figure 7

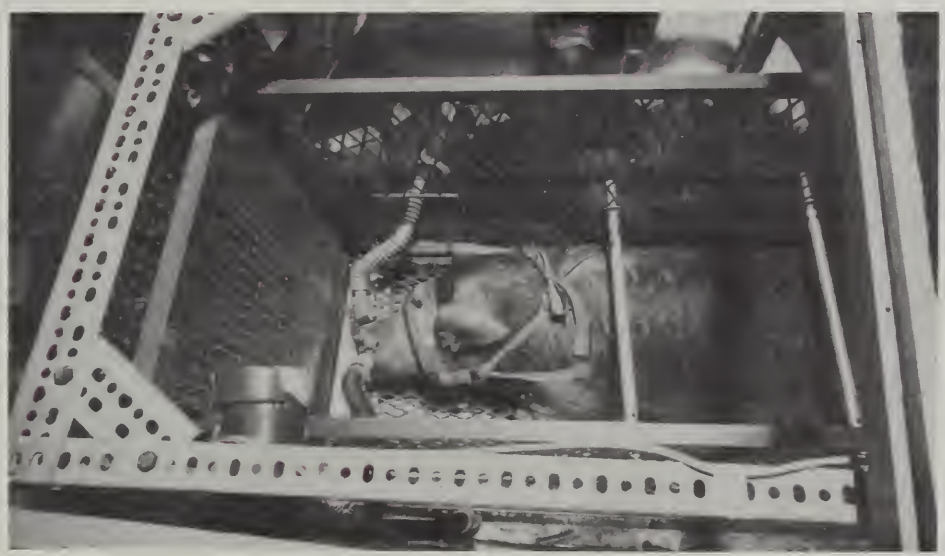

Figure 8.--Pig in position ready for moistures isolation test run.

Figure 8

INSTRUMENTATION

When the above-described system was placed in operation, an attempt was made to measure wet-bulb and dry-bulb temperatures by thermocouples in the inlet and exhaust air. Because of the small differences in air properties and low rates of airflow, it was next to impossible to obtain reliable data with thermocouples.

The method finally adopted has been described in detail by Morrison and Givens (6). Briefly, it involves using a moisture-measuring device in which a change in electrical resistance reflects

a change in humidity ratio. These devices were placed in the entering and discharging air-streams, and the resistors were made a part of a simple bridge circuit. The resulting voltage is proportional to the evaporation rate. Success with this method requires that the incoming air dewpoint be kept nearly constant. By timing the evaporation of given weights of water, a calibration constant can be calculated that eliminates the need for airflow measurements.

LITERATURE CITED

(1) Beames, R. M.
1962. A metabolism unit for use with male pigs. Queensland Jour. Agr. Sci. 19: 539-547.

(2) Bell, J. M.
1948. An adjustable cylindrical cage for use in metabolism studies with young pigs. Jour. Nutr. 35: 365-369.

(3) Bond, T. E., Kelly, C. F., Heitman, H., Jr.
1952. Heat and moisture loss from swine. Agr. Engin. 33: 148-152, 154.

(4) Brody, S., and Kibler, H. H.
1944. Growth and development. LIX. Resting energy metabolism and pulmonary ventilation in growing swine. Mo. Agr. Expt. Sta. Res. Bul. 380, 20 pp.

(5) Hansard, S. L., Plumlee, M. P., Hobbs, C. S., and Comar, C. L.
1951. The design and operation of metabolism units for nutritional studies with swine. Jour. Anim. Sci. 10: 88-96.

(6) Morrison, S. R., and Givens, R. L.
____ Measurement of small changes in water vapor in air. (Submitted for publication in ASAE Jour., 1965.)

(7) Yeck, R. G., and Kibler, H. H.
1956. Environmental physiology and shelter engineering. XXXVII. Moisture vaporization by Jersey and Holstein cows during diurnal temperature cycles as measured with a hygrometric tent. Mo. Agr. Expt. Sta. Res. Bul. 600, [19] pp.